sPHENIX EMCAL Module Production

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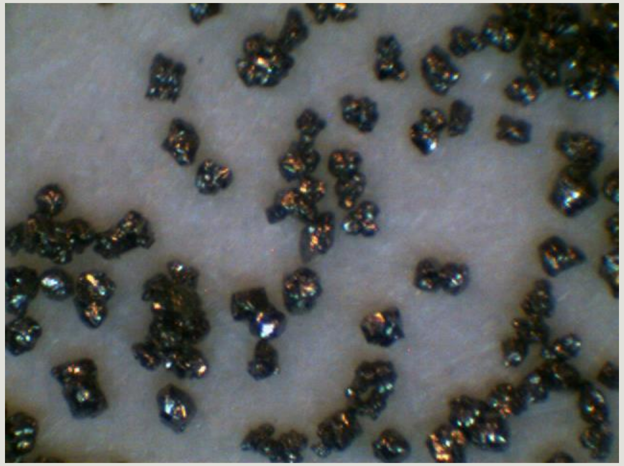
sPHENIX EMCAL Internal Review

August 20, 2015

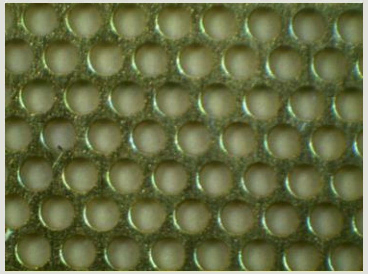
Absorber Modules



Tungsten:

Technon Powder (100 Mesh) from Tungsten Heavy Powder Inc.
<150um particle size, density ~12 g/cm^3

Plastic scintillating Fiber:



Kuraray SCSF-78 0.47 mm diam.
emission peak: 450nm

Epoxy:

Epoxy Technology EPO-TEK 301
mechanical epoxy, ~24h curing time

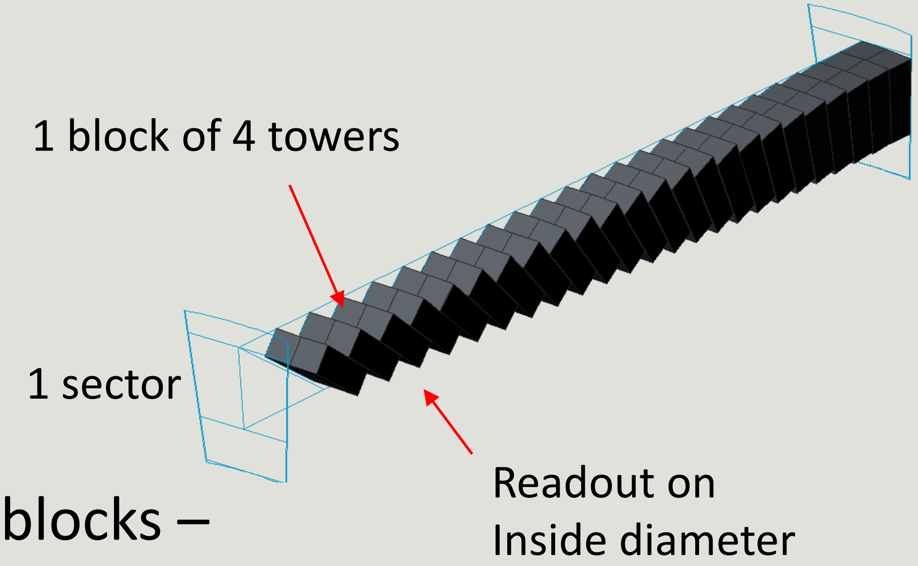
Metal Screens or meshes to position fibers:

etched brass or stainless steel 0.3mm thick

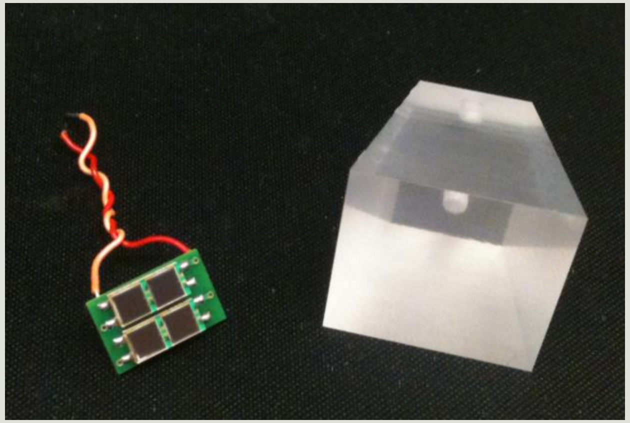
1mm center-center hole spacing

EMCal by the numbers

- 32 x 2 = 64 sectors
- Each sector has 8 x 48 individual towers
- 24,576 total towers
- If manufactured in 2x2 blocks, that would be 6,144 blocks – in 24 unique shapes, 256 units of each shape
- 750 13.5 cm fiber canes per tower = 2,500 km of fiber
- ~ 820 g tungsten powder per tower or ~20,150 kg total
- 24,576 light guides
- 4 passively summed sipms per tower x 24,576 towers = 98,304 sipms



Sipms and lightguide

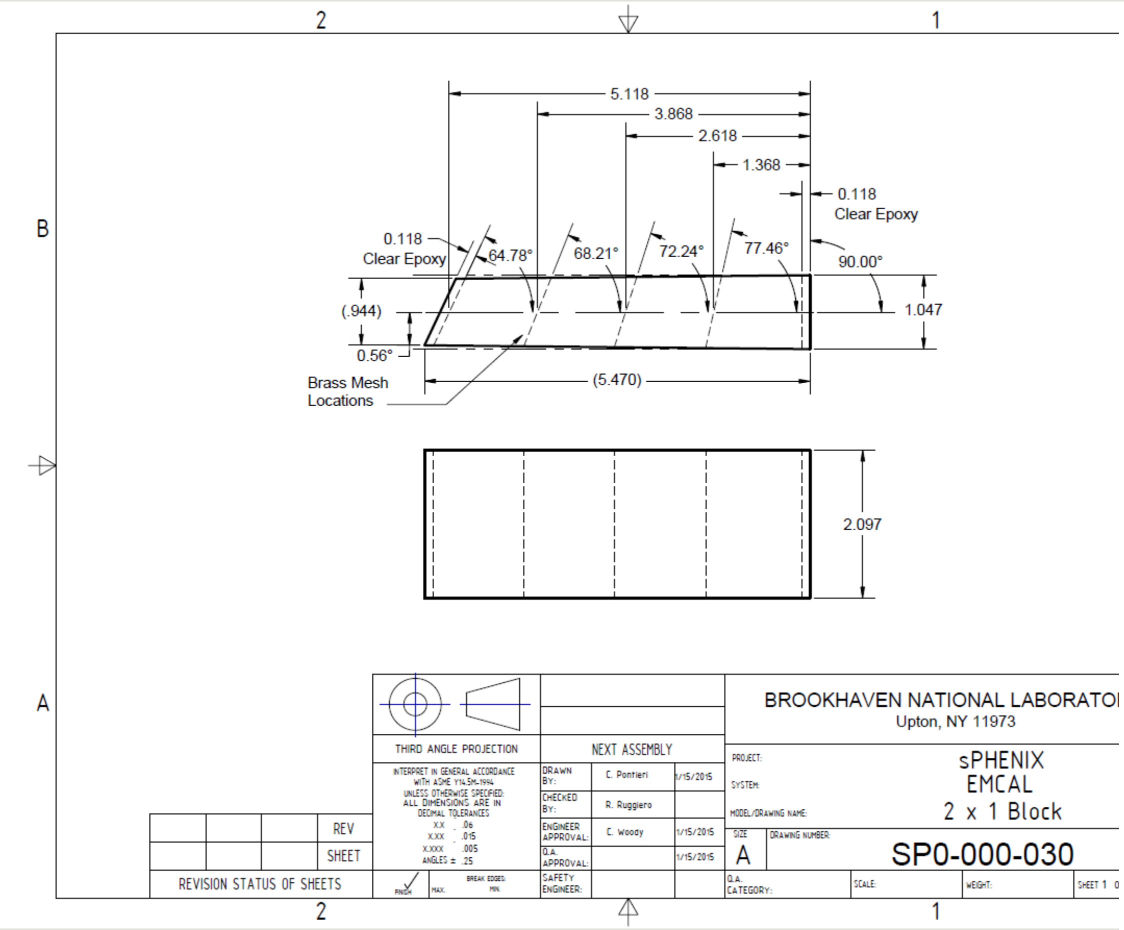


Progress

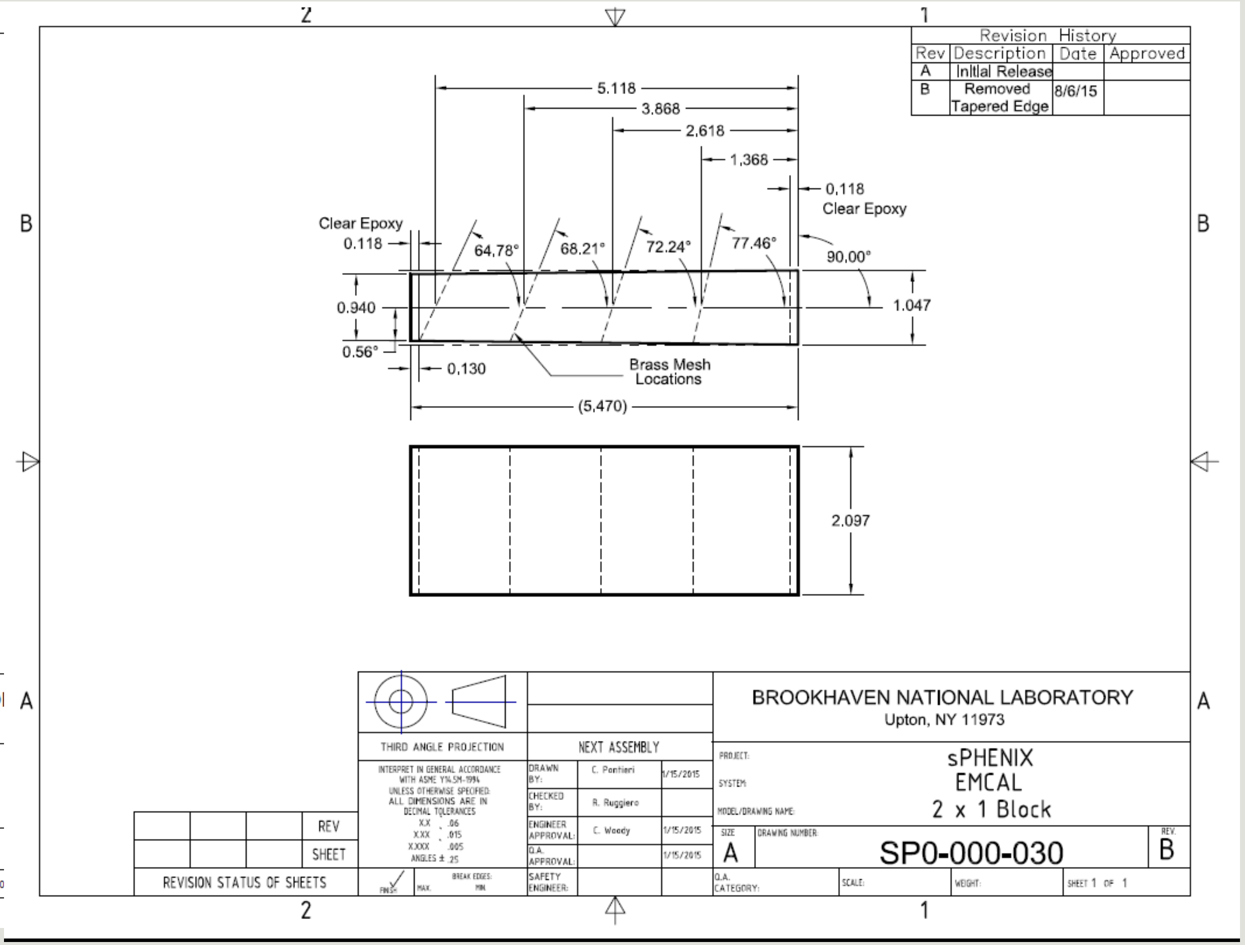
- Since converging on SPACAL type design, BNL and UIUC groups visited Oleg Tsai's lab at UCLA to learn module making processes
- Produced mold and 1D projective, tapered modules according to SPACAL design drawing
- Since then we have produced:

  5 1D projective, 2 tower modules

  3 2D projective, 1 tower modules
- Univ of Illinois group is also producing 1D and 2D projective modules by similar methods and is looking at ways to scale up the manufacturing process.
- Developed molds and 2 different techniques for producing 2D modules:
  - stepped meshes
  - tilted wire frames
- Designed screens and wire frames for 2D projective modules
- Worked out fiber/screen filling procedures and developed fixtures for production
- CAD and in-house Rapid prototyping have been very helpful in visualizing and improving the molds, assembly, and preparation processes with quick turnaround



Drawing of 1D projective SPACAL module being produced by UCLA, BNL, UIUC, and THP to develop and improve module production techniques.



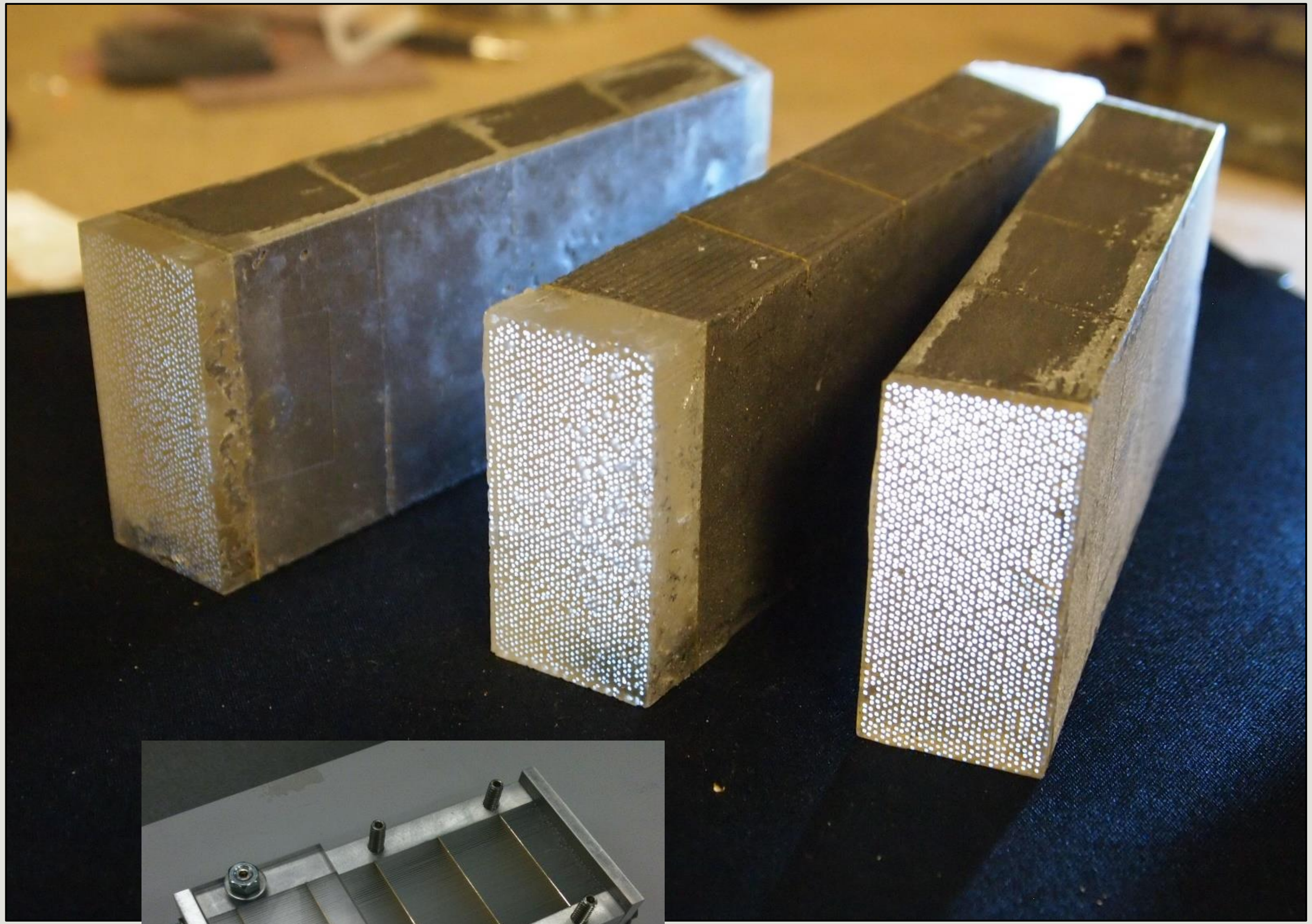
New module drawing (8/2015)
These modules will be produced at THP, BNL, and UIUC for a prototype detector to be tested at FTBF.

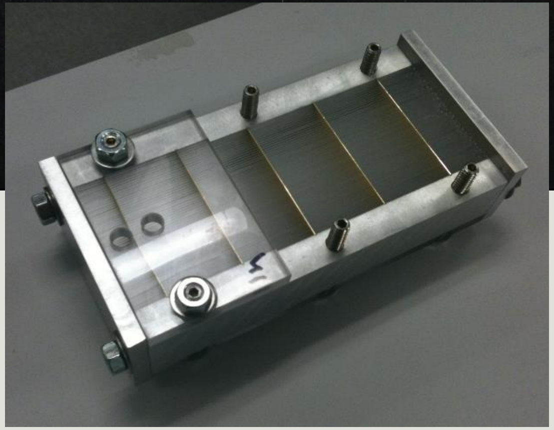
We have produced 5 modules at BNL so far, but have slowed the production of 1-D projective modules to make 2D projective modules

<u>Still some process issues:</u>

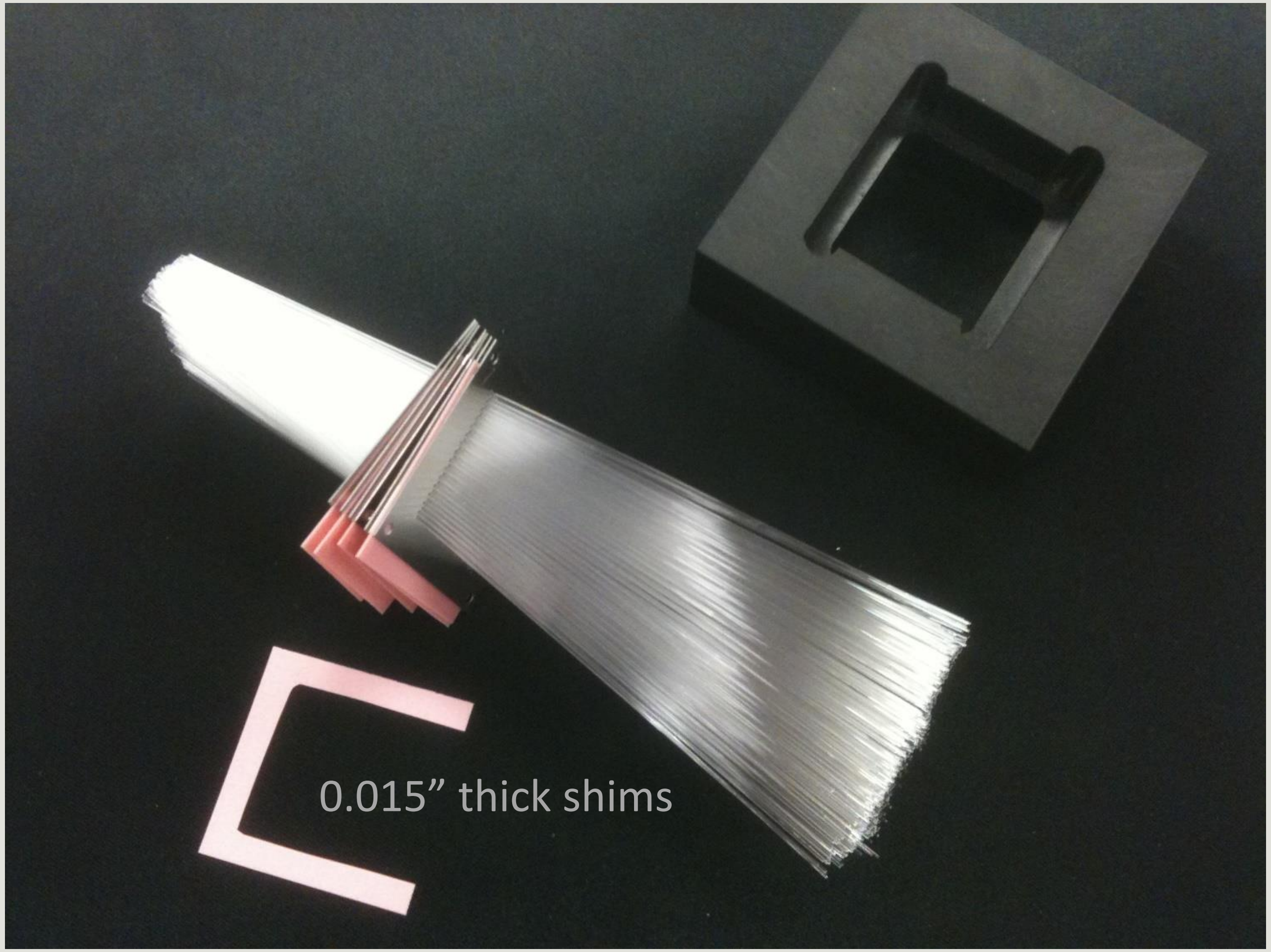
- bubbles/vacancies in clear epoxy/fiber ends
- surface finish
- fiber position uniformity?
  destructive testing required to see interior of modules
- module densities ~ 9.6-9.7 g/cm^3
  (W/fiber/epoxy region)
- density uniformity?
  destructive testing required

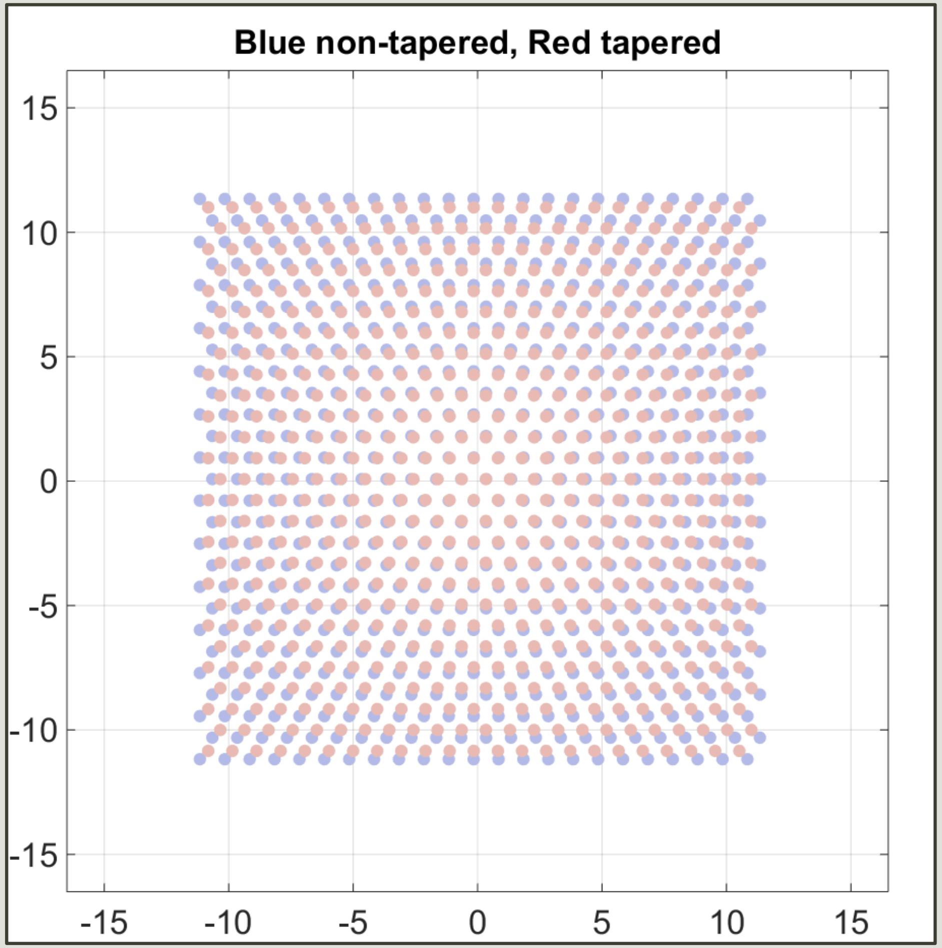
- Test of tungsten/epoxy cubes: density ~12g/cm^3





fiber/screen filling - 2D projective module



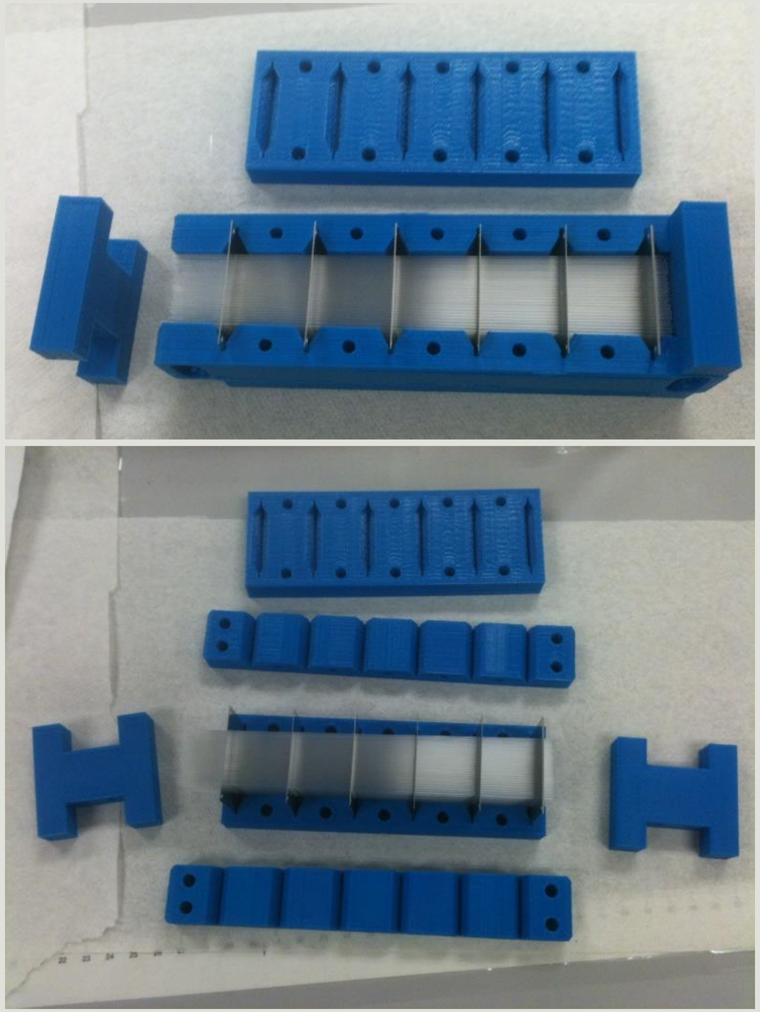


Overlaid 100% and 90% “stepped” screens

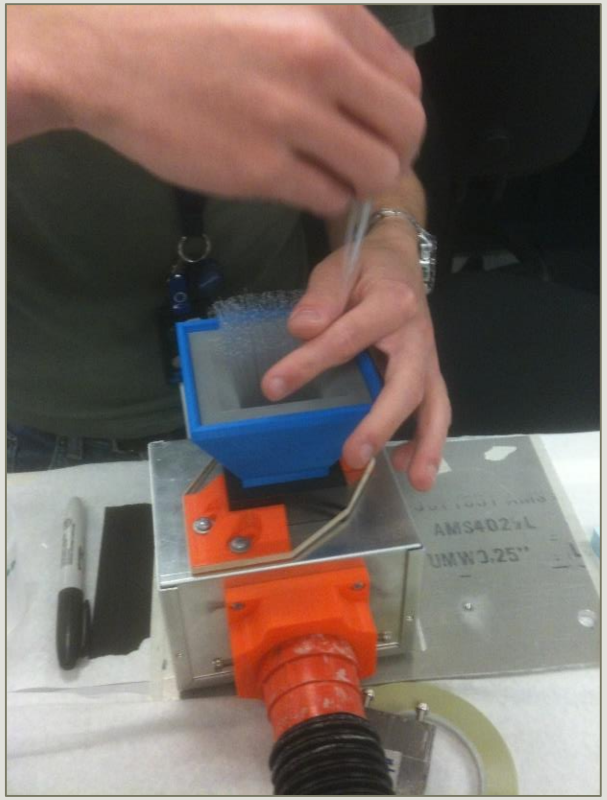
- Fibers are inserted into screens
- Screens are then separated and the fiber/screen assembly is put into mold for tungsten powder and epoxy filling
- Tungsten powder is poured in, then epoxy is infused.

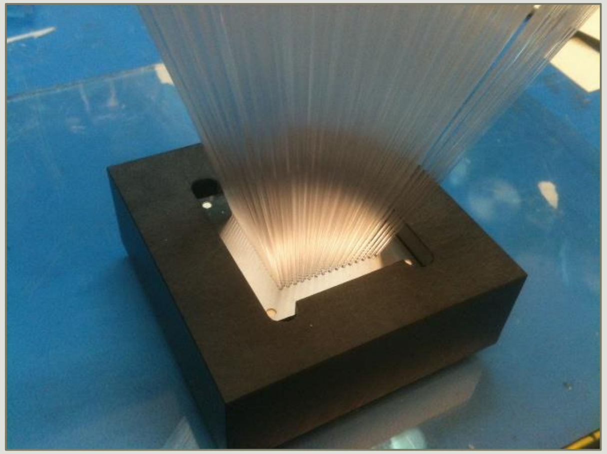
Refining process for loading fibers into screens

- Tuning shim spacing between screens to optimize filling
- Added a funnel/hopper to facilitate fiber loading
- Tuned funnel pitch with shim spacing
- Added vacuum attachment
- Loading times consistently < 10 min for stepped screens, faster for “straight through” screens and wire frames
- Scaleable to 2x2 tower modules?
  - tune shim spacing
  - alter hole size/shape

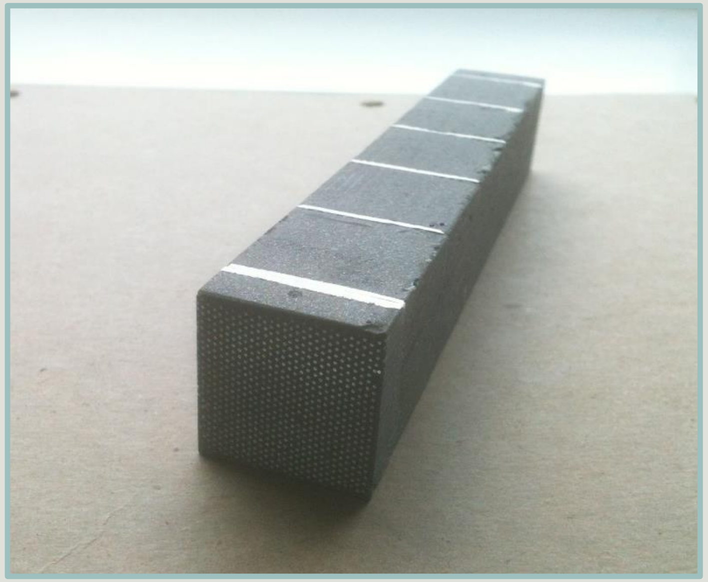


Makerbot mold sets

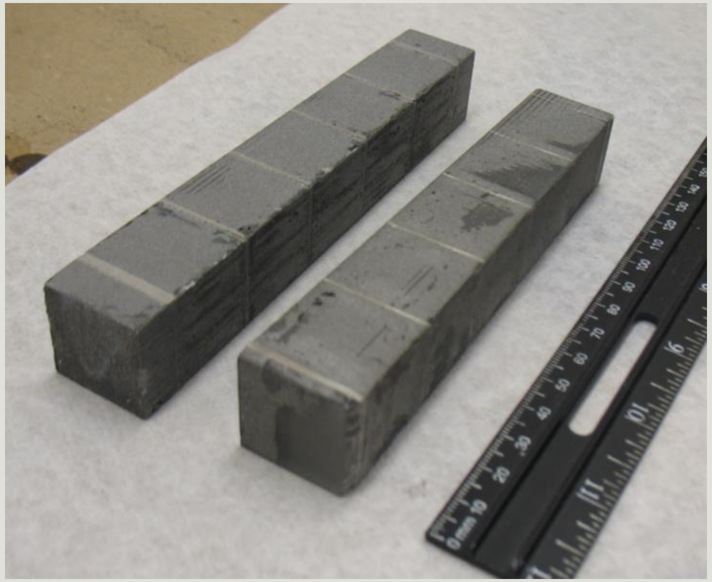


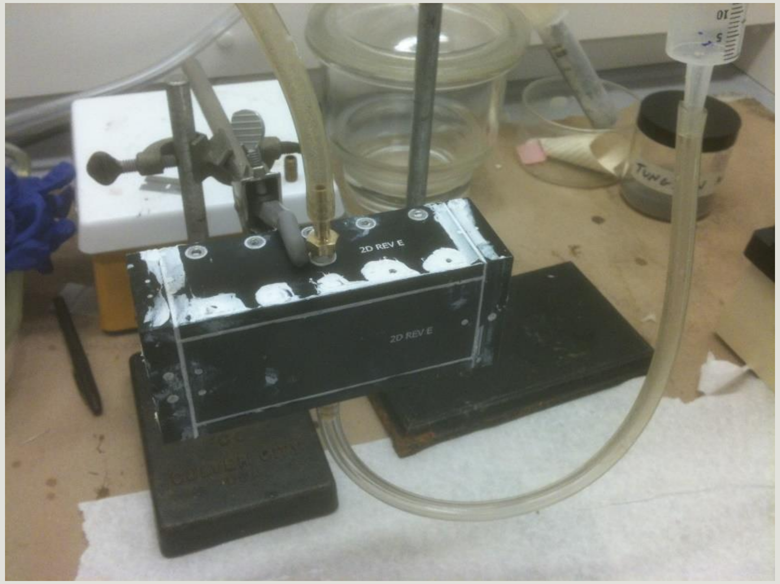


2D tapered module production
“stepped” meshes with tapered holes



- made progress with mold design - much tighter fit – no leaks
- still had some trouble getting module out of mold
- densities low: ~ 9 g/cm^3
- readout end finishing/polish
- Can we scale this process up to make 2x2 tower modules?
- Pros: fiber positions are well defined

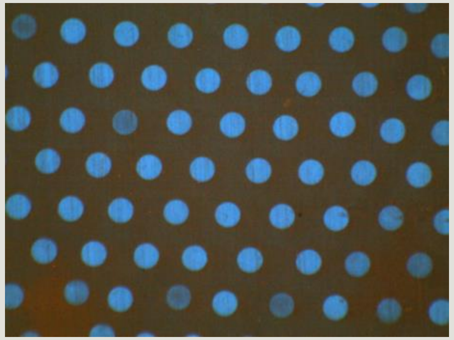


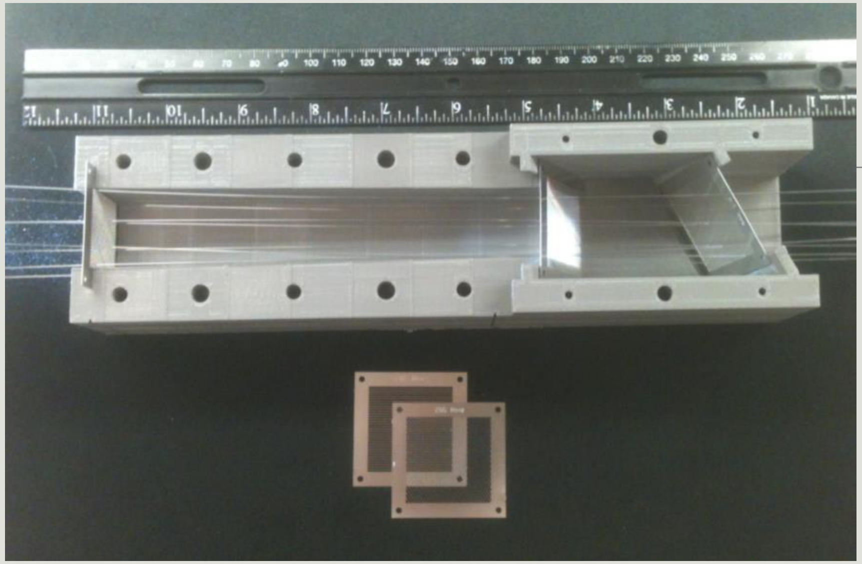


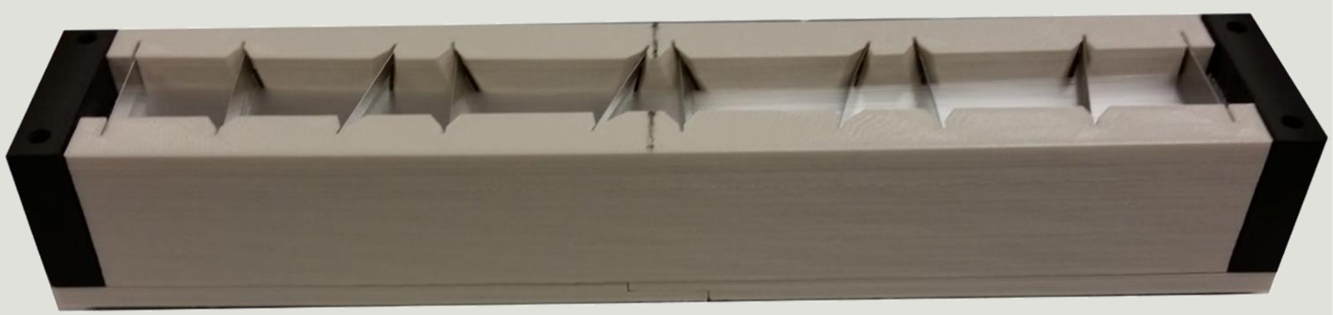
Mold produced by BNL Instrumentation Dept

TILTED WIREFRAMES

- Made initial proof of principle fixture
- filled stacked wire frames with fibers and inserted into fixture
- filling procedure seems non-problematic
- fiber positioning looks good
- Drawings for the mold are in progress
- Pros: fiber filling is easy (no taper)
  “bowtie” method yields 2 units per mold

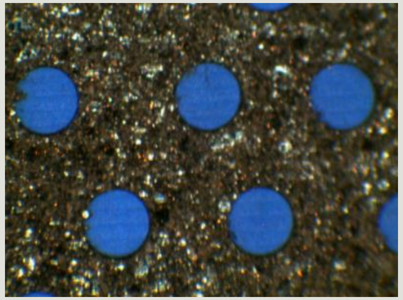


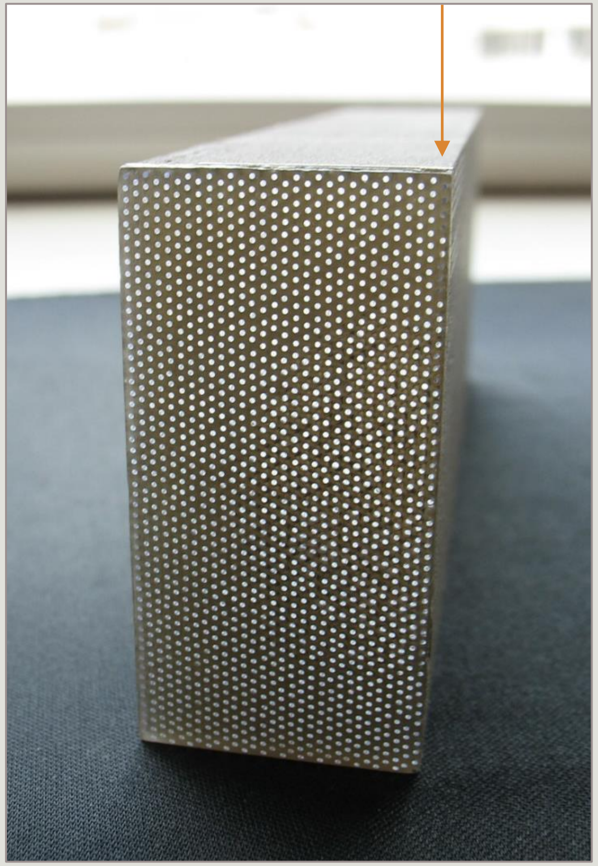




Tungsten/fiber modules from Tungsten Heavy Powder

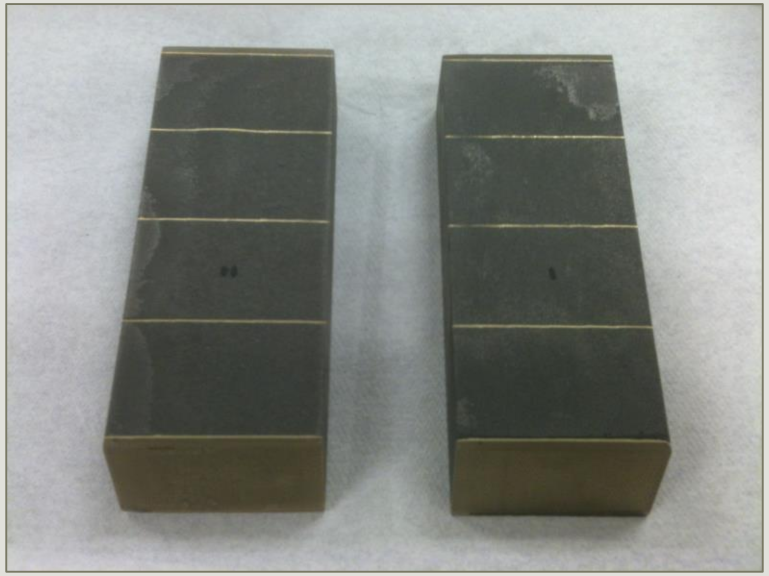
- Received 3 modules so far
- Densities ~ 9.7 g/cm^3
- Fiber fill – 100%
- Fiber position uniformity – good
- Screen alignment – good
- Problem with machining of fibers – damaged perimeter fibers
- They are working on a diamond end cutting process to eliminate the need for the clear epoxy end





Module #

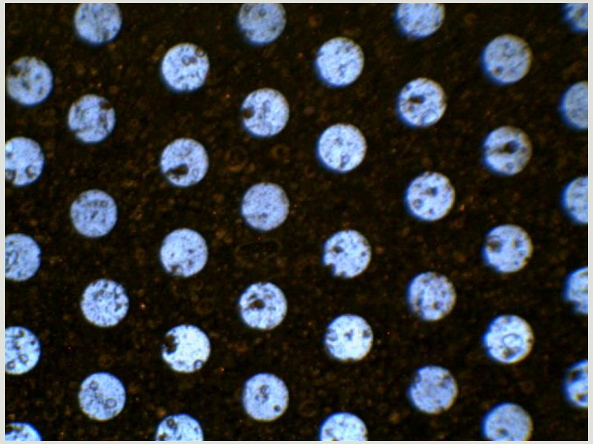
	I	II	III
module weight (g)	1699	1716	1682
module avg density (g/cm3)	9.07	8.98	8.96
W/epoxy region density (g/cm3)	9.75	9.63	9.74



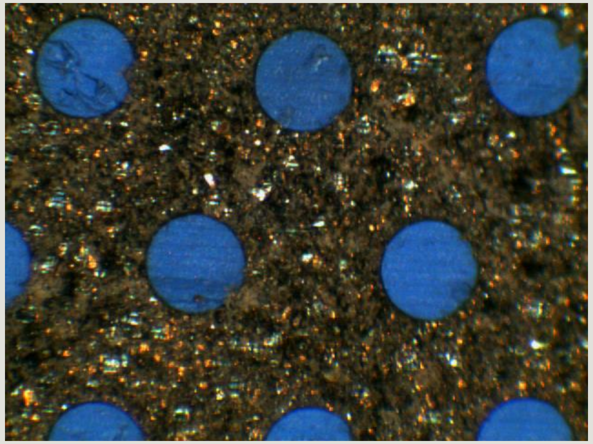
Module End finishing / polishing

The finish cut and polish of the module readout surface is important to maximize the light collection and make it uniform.

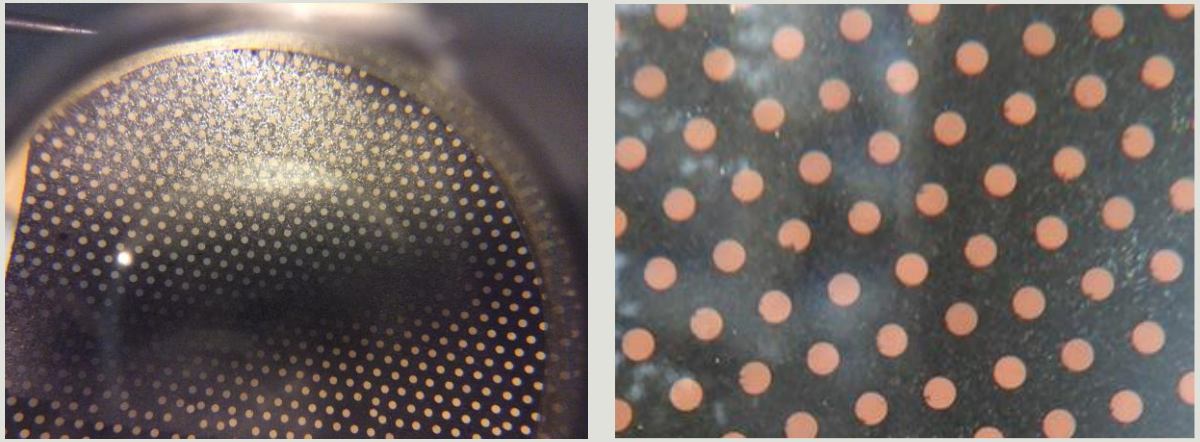
The initial module design includes a clear epoxy/fiber region at the end of the module. This allows for machining without the complication of machining a composite tungsten powder/epoxy/fiber surface. We are attempting to develop a process to make a quality diamond cut of the composite material, eliminating the need for the clear region. This would simplify the manufacturing process



Air bubbles



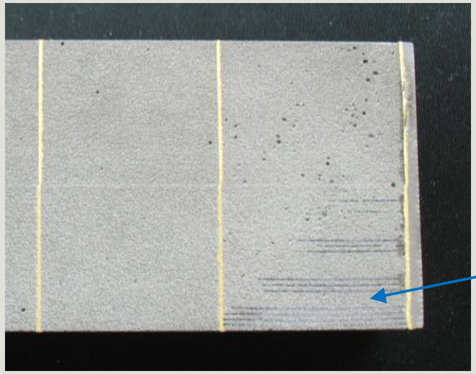
Chips and scratches

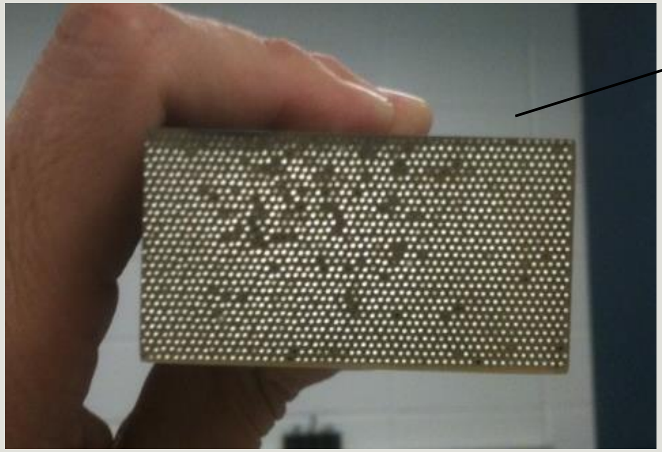


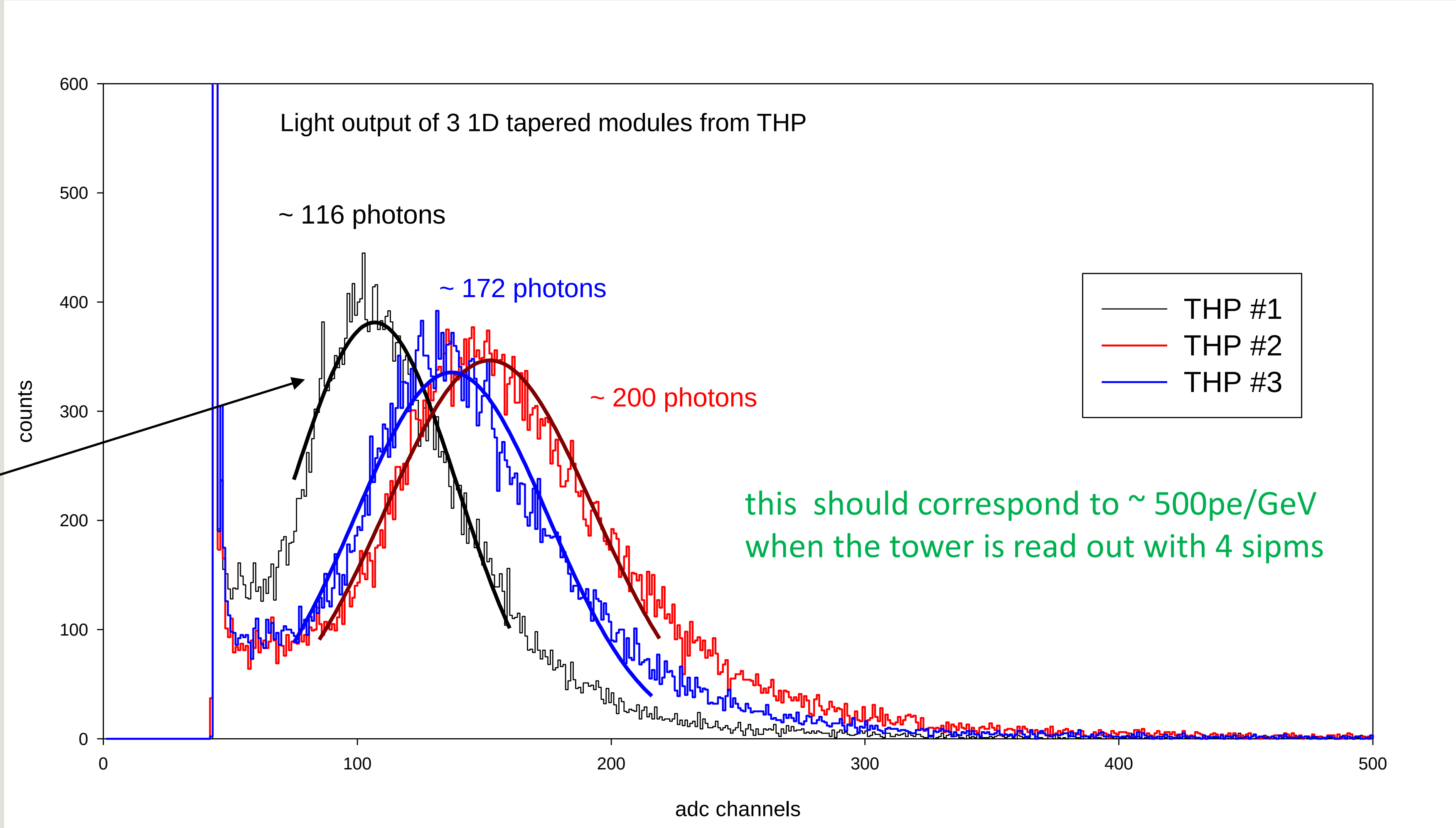
UIUC diamond cut

Measured light output of sample modules from THP

- 2" pmt readout optically coupled directly to module
- cosmic ray trigger



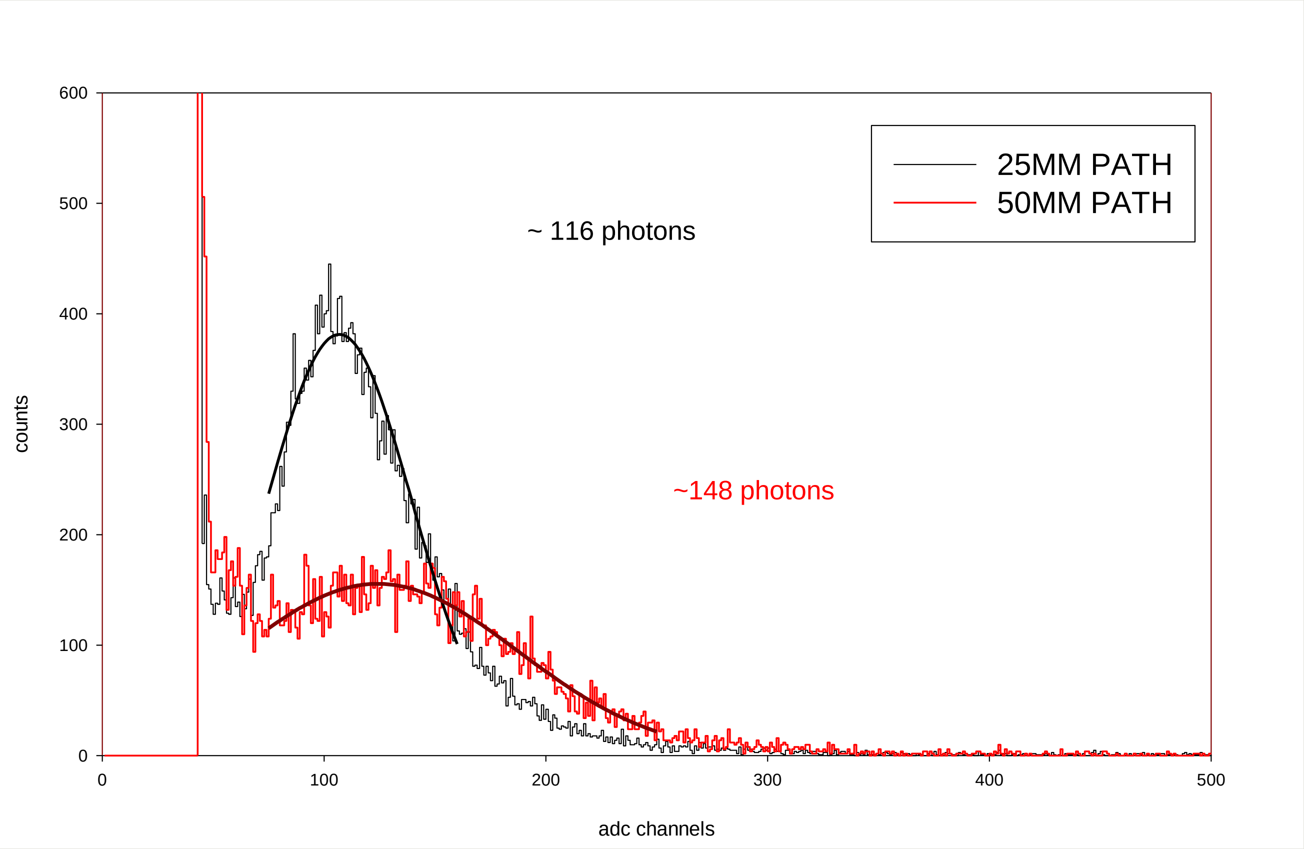


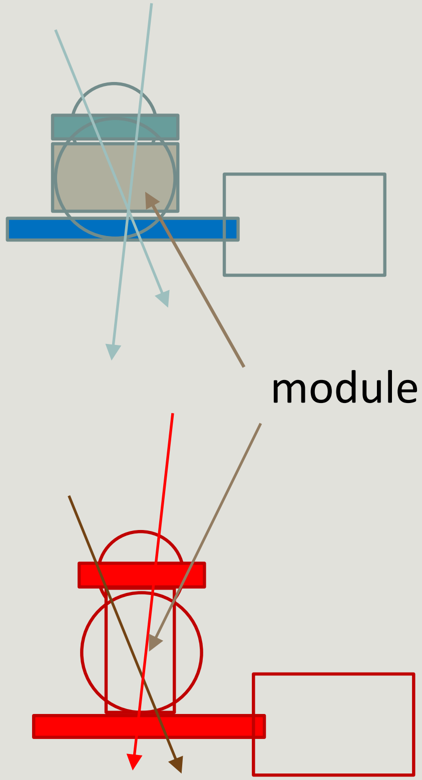


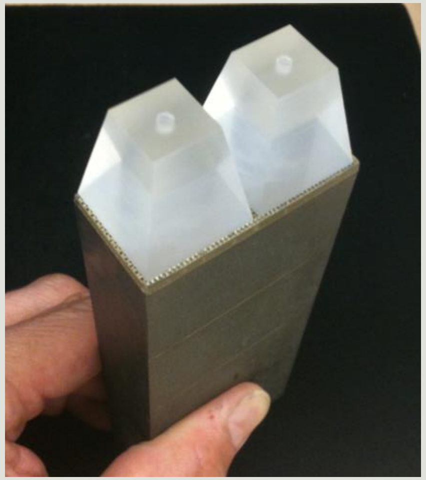
this should correspond to ~ 500pe/GeV when the tower is read out with 4 sipms

Measured light output of sample modules from THP

- 2” pmt readout optically coupled directly to module
- cosmic ray trigger
- clear peak will make module Q/A easy
- need to make measurement with light guides and sipms







Next step: attach light guides and repeat measurement with sipms

Issues and Concerns

- Mechanical tolerances – develop specifications for production. (For prototype modules: - 0.000”, +0.020”)
- Required machining of modules – Can we get finished modules out of the mold without machining?
- Density – get avg density > 10 g/cc and uniform throughout module
- Fiber positioning – uniform throughout module
  - Maintain uniform spacing from surfaces to avoid being nicked during machining
- Scaling up processes to produce 2x2 tower blocks/modules
  - Design screens to allow fibers to pass through
- Scaling up processes for mass production - more mold sets would parallelize process
- Module end finish/polish –
  - Is it necessary to have a clear epoxy end? Good diamond cutting would alleviate the need for this.
  - reflective end for LED calibration
- Light Guides design – efficiency and uniformity of light collection
- LED light distribution (for calibration)
- Mounting hole affect on module performance?